Geologic and Hydrologic Research on the Moana Geothermal System Washoe County, Nevada

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AUTHORS' NOTE

Much of the information that appears in this article was published in the Geothermal Resources Council Transactions, vol. 7, October, 1983, pp. 417-421. However, because the program is structured to continuously monitor the Moana system, and update the data base, this article represents the most recent information. The authors acknowledge the Geothermal Resources Council for their cooperation in this technology transfer effort.

ABSTRACT

The Moana geothermal area, located in southwest Reno, is the largest single low - to moderate -temperature geothermal resource in the State of Nevada presently employed for direct-use applications. Approximately 150 individual wells, reperesenting a total estimated investment of $5 to $7 million, are presently used to provide heat and hot water to more than 130 private residences, several churches and two large motels. Although most of the wells are constructed to meet the heating needs of individual homes, a large-scale district space heating system, designed to supply heat to 60 houses from a single well, is now being developed. Usable temperatures range from 50° to 99° C (122° to 210° F); well depths range from 60 to 400 m (200 to 1300 ft.). The number of new wells coming on-line in Moana is two to three per month. Development of the resource has been largely unregulated and questions dealing with reported reservoir temperature and water level declines, loss of artesian flow, and fluid disposal have recently surfaced.

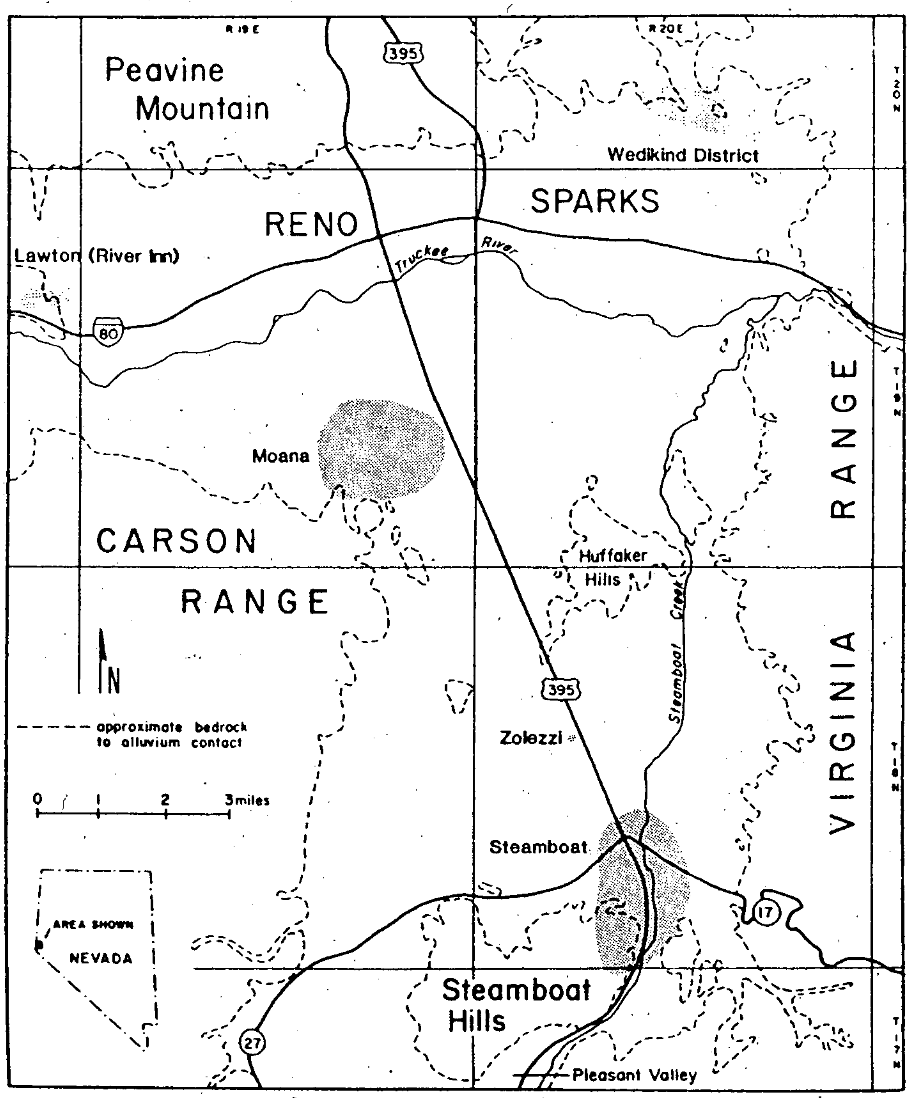

Figure 1: Location map showing geothermal areas in the Truckee Meadows (Modified after Bateman and Scheibach, 1975)

In October, 1982, a geologic and hydrologic research program began that was designed to provide detailed geothermal reservoir data to present or prospective developers. The program combines geophysical, geochemical, and geological surveys of the Moana resource area with a drilling program for 5 monitor/observation wells. Data from this program are supplied directly to developers as well as state and local government agencies to provide for prudent resource development. This

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paper summarizes the program elements and describes the present status.

INTRODUCTION

Bateman and Scheibach (1975) reported a total of "35 geothermal heating systems in use throughout the Truckee Meadows" (fig. 1), which includes Moana and Steamboat geothermal areas. Ghusn (in Trexler and others, 1982) listed nearly 120 individual wells in the Moana area alone. Today there are approximately 150 individual geothermal wells and that number is increasing by 2 to 3 wells per month.

Development of the reservoir has been largely unmanaged and unregulated. Moana is the site of Moana Hot Springs which reportedly ceased to flow 20 to 25 years ago. More recently, an artesian thermal well that discharged .3 to .5 l/s (5-7 GPM) also ceased to flow. In addition, Ghusn (in Trexler and others, 1982) has shown that reservoir contamination can occur in poorly completed wells. Additional problems include premature deterioration of copper heat exchangers or steel casing or both as a result of anode-cathode reactions. Disposal of fluids from geothermal wells is another problem that has been largely ignored.

This paper describes a research program that focuses on the geologic and hydrologic aspects of the Moana reservoir. This information is supplemented by geologic reconnaissance of the suspected reservoir rocks that outcrop to the north and west of Moana. A gravity survey that extended from Moana to Steamboat (16 km or 10 miles to the south) was completed to identify structures in the volcanic basement (north-trending normal faults) which are believed to provide the hot water to the shallow reservoir. Samples of thermal and non-thermal fluids were collected and analyzed for major, minor and trace elements, stable isotopes of hydrogen and oxygen (including tritium), and carbon-14. Many of the developers have cooperated by providing drill chip samples from the wells that are presently under construction. These data, coupled with temperature-depth profiles derived from the same wells, have been used to identify the reservoir rock.

The final phase of the program consists of long term observations and meausrements in strategically placed monitor wells. These wells were drilled to a total depth of 122 m (400 ft) (one was drilled to 244 m or 800 ft.) and cased with 64mm (2½ inch) diameter steel pipe. In addition to the lithologic information derived from each hole, the water levels and temperatures have been regularly monitored since July, 1983.

GEOLOGY

The Moana area is located along the western edge of the Truckee Meadows. It is a structural basin bounded on the east by the Virginia Range and on the west by the Carson Range, a spur of the Sierra Nevada. Late Tertiary and Quaternary faulting offsets Tertiary volcanics and volcaniclastic sediments and Quaternary alluvium and outwash. Late Quaternary alluvium and glacial outwash cover many Quaternary and Tertiary structures (Bingler, 1975; Mizell, 1975).

The oldest formations in the Moana area are Teritary volcanic and volcaniclastic rocks. These are generally andesitic flows, agglomerates and breccias with interbedded tuffs, and laustrine and diatomaceous sediments. These units are all considered to be part of the Kate Peak Formation (Bingler, 1975; Cohen and Loeltz, 1964; Thompson and White, 1964).

Uncomfortably overlying the Kate Peak Formation are Tertiary lacustrine and fluvial sediments. Thompson and White (1964) assigned these units to the Truckee Formation, first described by King (1878). Bingler (1975) identified those units assoicated with the Truckee Formation in the Truckee Meadows as the Sandstone of Hunter Creek. Lithologic descriptions of this formation include some clastic fluvial and volcaniclastic members previously associated with the Kate Peak Formation. Estimates of thickness of the Sandstone of Hunter Creek range from 914 to 1,219 m (3000 to 4000 ft.). The lowest member consists of a sequence of fining-upwards coarse gravels and clastic sediments. Overlying this member is a thick 205 to 914 m (1000 to 3000 ft) section of diatomite, diatomaceous siltistone and sandstone.

The Sandstone of Hunter Creek is overlain by outwash gravels from Quaternary glacial runoff as well as alluvial fan and sediment units from the surrounding ranges.

Pre-Holocene faulting resulting in a series of horsts and grabens in the Moana area and the western Truckee Meadows. These faults juxtapose late Quaternary and Tertiary units in several areas. Younger faulting offsets both Quaternary and Tertiary units.

GRAVITY SURVEY

This survey was used to delineate the basement structure from Steamboat north through Moana. Three hundred and fifteen stations were occupied, including 85 stations for which elevations were already known and 230 stations whose elevations were obtained by surveying. Gravity measurements were obtained with a LaCoste-Romberg Gravimeter.

Reduction of these data included calculation of the simple Bouguer anomaly according to the 1939 International Gravity Formula and terrain corrections calculated by Hammer (1939) for selected points and applied to all points. From the resulting complete Bouguer gravity values, an evenly spaced grid of values was interpolated by computer application of Laplacian cubic splining (fig. 2). The surface here is inverted; a gravity high appears as a depression.

Figure 2 shows a gravity high through the center of the Moana area. The gravity low (raised in the diagram) corresponds to the low density diatomite of the Sandstone of Hunter Creek. There is some indication that the northeast-trending structure in Moana corresponds to fault trends mapped in the area. This trend may also represent the contact between the Kate Peak andesite and the less dense sedimentary rocks. The large gravity high (depression) in the center of the diagram corresponds to outcrops of the Kate Peak andesite. Fault scarps here are difficult to identify because

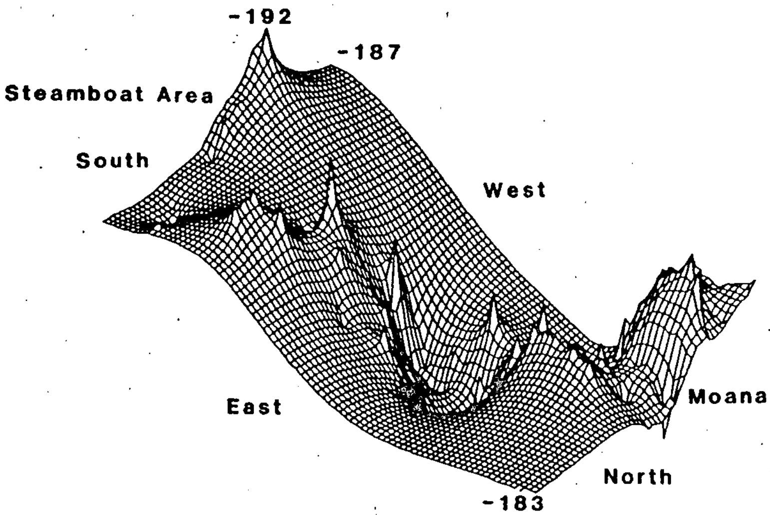

Figure 2: Three dimensional isosurface gravity map of the Moana and Steamboat geothermal areas.

offset along the faults is small.

THERMAL FLUIDS GEOCHEMISTRY

The Moana geothermal fluids are sodium-sulfate type waters that show little or no correlation with the sodium-chloride type water from Steamboat Hot Springs. Although relative percentages of cations are identical for fluids from Moana and Steamboat, the absolute concentrations of cations and anions are different by a factor of at least two. The thermal fluids from Moana are chemically similar to other low- to moderate-temperature geothermal fluids that are widespread throughout western Nevada.

Variations in the composition of Moana thermal fluids are directly related to the degree of mixing of thermal and non-thermal fluids. These variations are also observed in the gradual decrease in temperature from west to east across Moana. In general, along a west to east traverse, bicarbonate and magnesium increase and boron, silica, sulfate, and calcium decrease.

Major chemical analyses are supplemented by analyses of tritium and carbon-14. The carbon-14 isotopic age of Steamboat fluids ranges from 40 to 43 Ka (Ka = 1000 years). The carbon-14 isotope age of Moana fluids ranges from recent to 28 Ka. These are corrected values and older fluids are also high-temperature (> 85° C) and are closely associated with mapped faults in the westcentral part of the reservoir. North-trending faults are believed to be the ultimate source of hot water in Moana. However, recently completed wells in the western portion of Moana reveal, in both lithologic and temperature logs that the stratigraphic contact between the basement volcanics (Kate Peak Formation) and overlying sediments (Sandstone of Hunter Creek) is an important structure in the control and distribution of hydrothermal fluids in Moana. Tritium is virtually absent in the high-temperature waters in Moana (and Steamboat), but increases in tritium are observed in the cooler waters in the eastern part of Moana.

LITHOLOGIC AND TEMPERATURE-DEPTH MEASUREMENTS

Drill chips are collected regularly from well drillers and developers throughout Moana. In addition, temperature-depth profiles of geothermal wells are completed soon after drilling, but prior to hardware installation. Figure 3 is a typical lithologic log for the central portion of Moana. The accompanying temperature-depth profile shows that the highest temperatures are achieved and maintained in the dacite-rhyolite (Kate Peak andesite). To the west and north, the Kate Peak andesite is overlain by a thick section of diatomaceous siltstone (the middle member of the sandstone of Hunter Creek), and wells in this area must be drilled to depths of 255 to 396 m (800 to 1300 ft.) to reach high-temperature fluids.

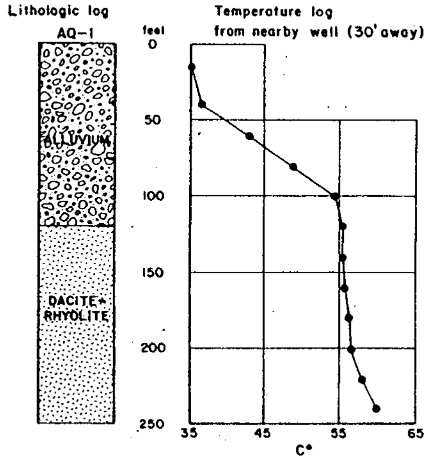

Figure 3: Lithologic log and temperature depth profile of a geothermal well in the center of Moana.

Although water temperatures in Moana are high (80° to 95° C), aquifier transmissivity is often very low. Many geothermal wells are completed with draw-off pumps that remove cooled fluids from the well bore. The pumped fluids are then replaced by hotter formation fluids. These spent fluids are traditionally disposed of in nearby irrigation ditches and storm sewers.

OBSERVATION/MONITOR WELLS

In order to accurately determine the effects of thermal fluid withdrawal during the heating season (October through March), five observation/monitor wells were drilled in strategic locations throughout the Moana geothermal area. Four wells were drilled to a total depth of 122 m (400 ft.). The remaining well was drilled to a depth of 244 m (800 ft.). All five wells were cased with 64 mm (2½ inch) diameter steel pipe to total depth. The bottom 6 m (20 ft.) of the casing has torch cut perforations and is gravel-packed. The top 15 m (50 ft.) of the wells have cement sanitary seals.

The remaining annulus interval is back-filled with drill cuttings.

All five wells encountered hot water; bottom hole temperatures range from 35 °C to 85 °C.

Monitoring these wells began in July, 1983, and includes measurements of static water level and temperature-depth profiles. To date, water levels have both increased and decreased in all wells and the changes appear to represent pumping rates rather than barometric pressure differences. Water level changes of as much as 1.2 m (4 ft.) have been recorded in one well.

Temperatures measured at 6 m (20 ft.) intervals for these wells have been remarkably consistent. Temperatures measured in portions of those wells that penetrate the Kate Peak Formation show no measureable change (less than 0.1 °C) in at least 7 months. Changes of -6.5 °C were recorded at a depth of 30 to 43 m (100 to 140 ft.) in one well. The temperature drop occurred with a gravel rich zone immediately above the reservoir rock.

PRESENT DEVELOPMENT

Geothermal well drilling and completion for individual residences is proceeding throughout Moana at a rate of 2 to 3 new wells per month. Carlson (1982) described a geothermal space heating system that is designed to deliver hot water from a single well to a privately financed space heating district, known as the Warren Estates, consisting of as many as 60 homes. The well was completed with a convection tube which redistributes the hot water throughout the well bore, effectively eliminating the heat loss zone near the top of the well. Figure 4 shows the results of a temperature-depth profile before and after installation of the convection tube. Several new churches and businesses have also developed plans for space heating. One existing motel that already uses geothermal waters for heating has expanded and will develop another geothermal well to supply additional heat to the new structure.

Corrosion of metal parts in heat exchangers occurs sporatically throughout Moana. Most newly completed wells now use fiberglass tubing

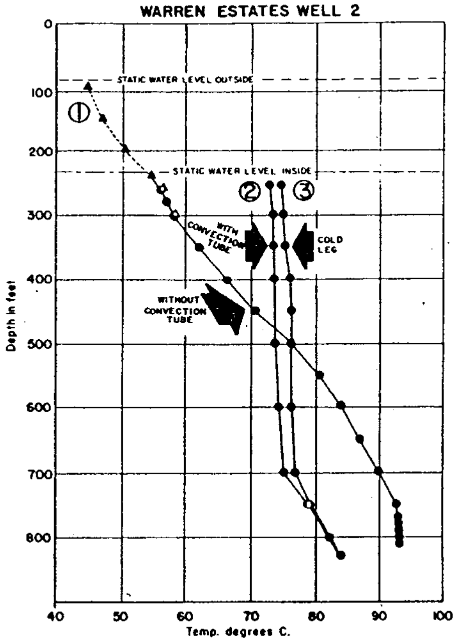

Figure 4: Temperature-depth profile of Warren Estates geothermal well at various stages of development.

as a heat exchanger instead of copper or steel. Because the thermal conductivity of fiberglass is much less than copper or steel, it is an excellent insulator; the water is less likely to cool from the well bore to the house. In addition, the fiberglass carries a 50 year guarantee.

Disposal of fluids from geothermal wells remains a problem in Moana. However, the first geothermal fluid reinjection well in Moana was recently completed and permitted at the Warren Estates geothermal space heating district.

CONCLUSIONS

Reports of overdevelopment and reservoir depletion of the Moana geothermal area are presently being evaluated with a combination of geologic, geophysical, and geochemical surveys coupled with down-hole measurements in observation wells. Geologic surveys reveal that a complex sequence of Tertiary sedimentary rockes and hydorthermally altered andesite constitutes the reservoir rock. Spatial variations in subsurface temperature are related to the distribution of hydrothermally altered Kate Peak andesite. A gravity survey completed in this area appears to have delineated the eastern-most boundary of the less dense sedimentary rocks. Geochemical analyses of Moana thermal fluids suggest little or no correlation with nearby Steamboat Hot Springs. Slight variations in fluid composition from west to east correlate with decreasing temperatures. Radiocarbon and tritium analyses suggest that the Moana thermal fluids originate from a seires of north-trending faults in the west-central part of the reservoir. These fluids then spread out laterally to the east, north, and south. Monitored measurements in observation wells throughout Moana show little or no change in temperature within the reservoir rock.

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Continued on Page 17